Program Guidance for Blast Overpressure Analysis

Purpose

The Center for Health Promotion and Preventive Medicine's (CHPPM) Ergonomics Program is responsible for analyzing blast overpressure data using the BOP-HHA software developed by Titan Corporation and for establishing guidelines to ensure the integrity of the analyses it conducts.

BOP-HHA was originally designed as a rapid assessment method that would allow someone with minimal technical background to directly enter data from a weapons test, process it, and obtain a risk assessment. To that end we are striving to keep this assessment process as uncomplicated as possible without degrading the quality of the report.

What is BOP testing?

Blast overpressure testing is the process of collecting data that can characterize the changes in air flow and density that occurs as a result of detonation of an explosive device.

Why is blast overpressure important?

Blast overpressure is important because exposures can produce injury. The risk of injury is related to the mechanics of the pressure wave and the physical properties of the tissue contacted. Air-containing organs such as the heart, lung, esophagus, and stomach are relatively more susceptible to damage than denser tissues such as bone.

How does the CHPPM perform the non-auditory analysis?

Analysis is performed by a software program called BOP-HHA. This software takes time and pressure data from the specially designed sensors called blast test devices (BTDs) and uses a biomechanical model of the chest wall to calculate the amount of mechanical force that the blast wave would yield to a person occupying the position at which the BTD is located. Next, the software estimates the probability of lung damage that the blast could produce based upon data from animal experiments. (Although BOP can damage any air-containing organ, the lung was selected as the organ upon which to base BOP-HHA's analysis because of the severity of the consequences of lung injury.)

When should blast overpressure data be collected?

BOP testing should be conducted whenever analysis of the auditory test data demonstrates that the intensity of the blast pressure wave dictates that single hearing protection is needed to protect against exposures of 5 or less rounds.

How do I request CHPPM's assistance for analyzing blast overpressure data?

To obtain CHPPM's assistance for analyzing blast overpressure data, submit a memorandum requesting a Health Hazard Assessment (HHA) thru the U.S. Army Materiel Command (AMCPE-SG-H/LTC Siddique), 9301 Chapek Road, Fort Belvoir, VA 22060-5527

How should the weapon system test be designed?

The system developer and the weapon tester are responsible for selecting the equipment, data processing methods, and quality control procedures needed to generate good quality traces that can be used for BOP analysis. The tester is responsible for executing a test plan and generating data that is accurate enough to be used as a basis for making decisions about health risk. For statistical significance, testers should strive to include at least five rounds for each firing condition tested.

How should blast overpressure data be collected?

In order to be analyzed at CHPPM, BOP data must be collected by an approved blast test device (BTD). A blast test device consists of a cylindrical metal tube containing an array of four pressure sensors (Ref: Appendix 1). To date only two BTDs are approved for use 1) the standard thirty-inch device developed according to specifications established by JAYCOR is approved for testing both outside and within enclosures (inside vehicles, equipment or buildings) and 2) a twenty-four inch BTD validated by testers at the US Army Yuma Test Center is approved only for testing outside of enclosures. Since it is not possible to attest to the validity of data collected by any devices other than the two just described, CHPPM will not make health hazard assessments collected on unvalidated devices.

Where should BTDs be placed?

The system developer is responsible for determining where the BTD should be placed. In order to ensure that blast test data will accurately represent the hazard, BTDs should be placed in locations that weapon crew personnel will actually occupy during live firing. Failure to locate BTDs properly will invalidate the data collected at the location(s) of the misplaced devices. Upon request, in special circumstances, CHPPM may provide suggestions on BTD placement for the test plan.

What data do I need to send in order to accomplish the BOP analysis?

The CHPPM needs the following data to complete the analysis:

a. Description of the weapon system and its projected usage

    1) An estimate of the maximum number of shots to which weapon crew personnel will be exposed on a typical training day.

b. Description of the weapon test

    1) A description of the purpose of the test.

Example: "*The objectives of this test to assess the peak magnitude and B-duration of sound signatures produced by the XM1028 cartridge when fired from the M1A1 Abrams tank and conditioned to the hot operational temperature (49°C/120°F), to measure the non-auditory blast overpressure at the chest area of each crew member in the M1A1 Abrams Tank and to determine whether the peak magnitude and B-duration of the sound signatures meets or exceeds the impulse-noise limit, category Z (MIL-STD-1474).*"

2) A list of the firing conditions and the rounds associated with each condition

Example:

	Conditions		
Round(s)	QE	Temp	Hatch
1 – 6	17	120	Opened
7 – 12	17	120	Closed
13 – 18	45	120	Opened

3) A copy of the test plan and test diagram

4) A description of the of BTDs used, including device length

c. Properly formatted data (Ref: Appendix 2)

The data should be formatted in a manner consistent with the JAYCOR Information Format (JIF) as explained in Attachment 2: JAYCOR Information File (JIF) Format. Any data not JIF formatted will be returned immediately to the sender for conversion.

How should the data be delivered?

Data should be delivered to CHPPM on a CD ROM. We are capable of receiving smaller data sets via FTP as well. Contact the CHPPM Ergonomics Program at COM: (410) 436-2736 or DSN: 584-2736 for details.

Mailing Instructions

United States Postal Service (USPS):

Mr. Don Goddard
USACHPPM
ATTN: MCHB-TS-OER
5158 Blackhawk Road
APG, MD 21010-5403

Federal Express (FedEx) and United Parcel Service (UPS):

Mr. Don Goddard
CHPPM Ergonomics Department
ATTN: MCHB-TS-OER,
Stark and Sibert Rd., Bldg E1570
Aberdeen Proving Ground, MD 21010.

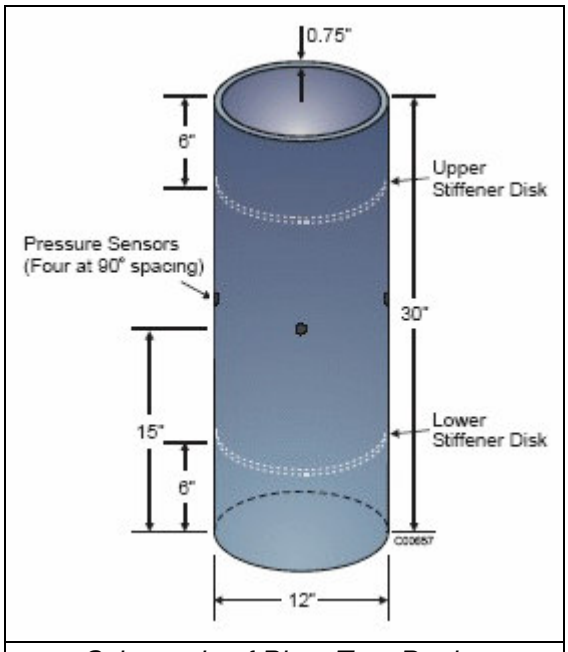
APPENDIX 1: Blast Test Device (BTD) SPECIFICATIONS

Specifications

The Blast Test Device (BTD) measures the external pressure loading on a human thorax due to blast overpressure. The BTD, Figures 1 and 2, is a 0.75 inch thick, 12 inch outside diameter, 30[1] inch long, 6061-T6 aluminum tube. Two 0.75 inch thick internal stiffener disks, Figure 2, are fastened to the interior of the cylinder, one 6 inches from the bottom and one 6 inches from the top. Four 1000 psi PCB Electronics model 102A04 pressure transducers are screw-mounted into the cylinder with their faces flush with its surface. The pressure sensors are evenly spaced along the circumference at mid-height (15 inches from the base) of the cylinder. A PCB model 481A20 16-channel signal conditioner powers the pressure sensors.

The PCB model 102A04 pressure sensor has an integral shock mount specifically designed for shock tube and blast wave measurements. To insulate the pressure sensor from flash temperatures at the blast front, a 0.1 inch thick layer of General Electric RTV type 106 silicone rubber coating is applied to the surface of the sensor diaphragm.

Blast Test Device with Signal Conditioner



Schematic of Blast Test Device

[1]Currently both 24 and 30 inch BTDs are approved for data collection.

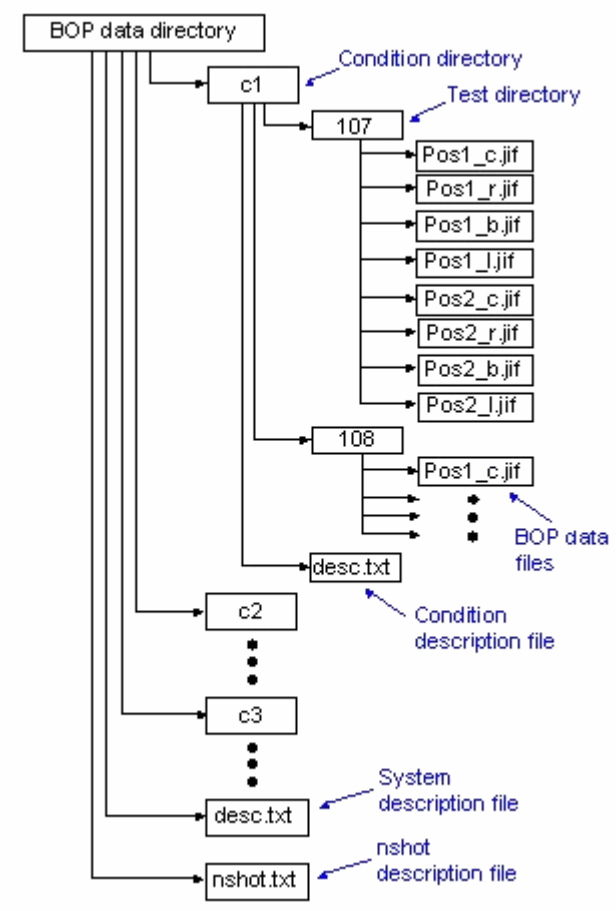
[2]For further information contact: Michael J. Vander Vorst, Jaycor, Inc., 3394 Carmel Mountain Road, San Diego, CA 92121-1002.•Tel: 858.720.4124.•Fax: 858.720.4156

APPENDIX 2: JAYCOR INFORMATION FILE FORMAT (JIF) SPECIFICATIONS

BOP Test Data

Overview

The Blast Overpressure (BOP) test data are time dependent measurements at various crew positions of the pressure field arising from the use of a weapon system for a given set of firing conditions. The measurements are made with a Blast Test Device (BTD), incorporating four pressure transducers spaced 90 degrees apart, mounted along the circumference of a steel cylinder at a given elevation. The four pressure signals recorded at each crew position represent the pressure felt on the chest, right side, back, and left side of a crew member. The BOP test data are a necessary part of the complete set of input data required for a BOP-HHA calculation. The pressure traces used by BOP-HHA must have any signal bias removed by the data provider, and must be filtered appropriately to prevent aliasing effects due to digitization of analog data at finite sampling rates. Failure to adhere to these practices could result in an incorrect health hazard assessment of a weapon system. The user must provide a directory path to the BOP test data, and the data must be structured and formatted in a prescribed manner, as described below.



Directory Structure

The directory structure defines the various firing conditions, and the shots (rounds) fired for each condition. In addition, the position names and gauge locations on the BTD are inherently defined by a simple file naming convention. Provisions are also made for special files within the directory structure containing word descriptions for the system and for each condition. The directory structure conventions eliminate the need for specification in the user interface of conditions, accompanying shots, and crew positions for a weapon system. A sample data structure is shown below.

Each condition must be assigned its own directory within the BOP data directory. Condition directory names must begin with the letter "c", which can be in lower or upper case. The remainder of the condition directory name must be the condition number, an integer from 1 to 30. Hence, condition directories must be named c1, c2, c3 ... c30. All data that apply to a given shot number for a condition must be contained within a test subdirectory of the condition directory. The name of a test (or round) directory must be purely numeric, a positive integer from 1 to 99999. The BOP pressure trace files for the four locations on the BTD and for all positions of the BTD in the weapon system are contained within the test subdirectory for each round. Optional files named "desc.txt" can be inserted in the BOP data directory and in each condition directory, containing text describing the weapon system and the conditions, respectively. Text from these files will be inserted into the printed output files from BOP-HHA. Another optional file "nshot.txt" can also be placed in the BOP data directory. This file can be used to specify different numbers (nshot) of repeated shots for each condition, to be used in RAC calculations.

The same shot numbers can be used in different condition directories. For example, the three shot numbers 1, 2, 3 can be present in each of the condition directories c1, c2 and c3. The BOP data for the identically named shots will differ, of course. In many cases, the shot numbers are unique across conditions, and represent test numbers or "round" numbers fired. The naming of the shots depends on the personal preference of the tester. If the shot names include non-numeric characters, the names must be mapped to purely numeric ones in order to be used by BOP-HHA.

BOP-HHA is quite flexible with regard to omitting data for a given condition or round. For the same condition, some rounds may not have all positions present, due to some gauges malfunctioning. Also, some conditions might not have data for all possible positions, among all of their rounds. A master list of all unique positions among all conditions is maintained. If data are missing, the print-out usually reflects that situation by showing blanks where some results would ordinarily appear, or displaying an appropriate message. Useful output data still appear for the data that are present. If data are unavailable for one to three of the four gauges mounted on a BTD, BOP-HHA will substitute missing traces with a logical counterpart of the trace or traces that are present.

In the sample data structure shown above, there are three conditions corresponding to directories c1, c2 and c3. Two test subdirectories are shown for condition 1, corresponding to test numbers 107 and 108. Files containing BOP test data are shown for two positions, "Pos1" and "Pos2", for test 107. The contents of an optional file "nshot.txt" for this sample could be:

Condition	nshot
1	5
2	10
3	3

In this example, nshot would be set to 5, 10 and 3 for conditions 1, 2, and 3, respectively. In order for the information in file nshot.txt to be used in a RAC calculation, check boxes on the user interface must be set appropriately (refer to the description of Min Shots/Day.) The first line of the nshot.txt file, "Condition nshot", is a descriptive header line and must be present. The condition number and nshot value are in free-field format. They must be separated by at least one space.

BOP File Naming Convention

The individual pressure trace files must follow a prescribed naming convention. The first part of the file name indicates the crew position at which the measurements were made. This should be a string of 1 to 7 alphanumeric characters with no embedded blanks allowed. For example, "Gunner", "Loader", "#1man", are valid examples of position names. The next character of the file name should be an underbar (_) character. The character following the underbar should be one of the letters, "c","r","b" or "l", denoting the chest, right, back and left gauge positions on the Blast Test Device. Additional characters between the BTD gauge position character and the file name extension are not allowed. The extension must be "jif", indicating that the files are in JAYCOR Interchange Format (JIF). See also the description of Trace Data Format. JIF binary files with extension "JIB" can also be read, but their use is not recommended for reasons of portability. If JIB files are used, the JIB version must be 32 bit and not 16 bit. The file naming convention can be summarized as:

position_x.jif

where "position" is a 1 to 7 character descriptor for crew position, and "x" denotes the letter c, r, b or l, representing the chest, right, back and left positions on the BTD. Lower or upper case characters can be used in these file names.

Trace Data Format

The BOP trace data must be in JAYCOR Interchange Format (JIF). Each JIF file constitutes a pressure versus time trace for a given location on the Blast Test Device. The JIF format is a free field text format which allows variables names and units to be stored along with the data. A listing of a sample time history JIF file follows this description. For the sake of portability and simplicity, the JIF format here is subject to the following restrictions:

(1) Header lines in a file must appear exactly as shown. These are the lines including and preceding the record: "data(Time,Pressure)".
(2) Units of time and pressure must be ms and kPa, respectively.
(3) The time and pressure variables must be named "Time" and "Pressure".
(4) Only text files are permitted (use of binary counterparts "JIB" are not recommended.)
(5) A file can contain only a single pressure time history.
(6) The time and pressure data must appear in consecutive pairs.
(7) The value of time must precede the pressure in each pair.

Sample contents of a JIF file

```
float(Time[ ],Pressure[ ]);
units(Time,"ms");
units(Pressure,"kPa");
data(Time,Pressure)
        0.000       0.000
        0.820       0.000
        1.640       -95.909
        2.460       5754.511
        3.280       -863.177
        4.100       -4603.609
        4.920       -3884.295
        5.740       -2781.347
        6.560       -4651.563
        7.380       -2925.210
        8.200       4315.884
        9.020       4651.563
        9.840       1774.308
        10.660      -911.131;
```

The four header lines should be specified exactly as shown above. The left and right lower case bracket characters ([ ]) should always follow the variable names "Time" and "Pressure" in the first line of the header (the "float" descriptor line). It is unnecessary to specify a point count in the JIF file. The interleaved time and pressure data can be in free-field format, with each consecutive value separated by one or more spaces. Commas cannot be used as delimiters. Blank lines can appear anywhere and are ignored. The time and pressure data can be given in either FORTRAN "F" or "E" format. At the end of the time and pressure data block, a semicolon character (;) must appear. This character can appear at the end of the last line of data, or on the next line by itself. An error will result if the semicolon character is omitted.